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ENVIRONMENT AND LIFE

By

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CHARLES C THOMAS · PUBLISHER
SPRINGFIELD, ILLINOIS · BALTIMORE, MARYLAND
1930

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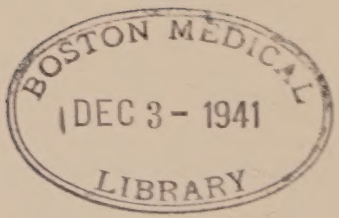

First Published, 1930
Manufactured in the United States of America

TO

DICK

WHO HAS

MADE

ENVIRONMENT PLEASANT

AND

LIFE WORTH WHILE

PREFACE

The scientific study of living things should perhaps benefit mankind chiefly by showing average people how to live from day to day in the world as it exists at the present stage of its evolution. In this little book an attempt is made to present in a non-technical way certain biological facts and theories that are related to everyday life. The six chapters essentially represent certain of the lectures which were given in Keiogijuku University while the writer was serving as Visiting Professor of Biology in 1929. Grateful acknowledgment is made to Mr. Arthur Jorgensen who read the manuscript and made valuable suggestions. The decorative sketches are from the pen of Anna Marshia Jackson.

Tokyo, January 1, 1930.

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ENVIRONMENT AND LIFE

CHAPTER I

Animals and Environment

The Twentieth Century is the Age of Science. A man who lives in the modern world enjoys privileges and comforts that were unknown to his ancestors. Most of the necessities and luxuries of modern civilization have been made possible through the application of scientific knowledge to the problems of everyday life. Scientists have reason to feel proud of their discoveries. They have made the world better—more convenient, more comfortable, and more enlightened. They have through long ages fought against superstition and prejudice. Their most trusty weapon has been knowledge. Yet science, like other branches of human learning, is today perhaps as remarkable for the things that it does not understand as for those that it does. For example, many facts are known about the phenomenon that is called light, but science has not yet been able to say exactly what light is. In the same way, much is known about life and living things, but no one knows what life is. Perhaps scientists can never discover the secrets of life. It may be that such knowledge

is beyond the capabilities of the human mind, but as long as there are scientists there will be unceasing attempts to carry the standards of truth and understanding into the barbarous land of ignorance. The side arms of science are the ruler and scales. Science does nothing but weigh and measure. A scientist's day is usually taken up with tiresome determinations of how much, how far, how many, and how fast. At times there are exciting days when a scientist puts his observations together and discovers a larger or a smaller "how," or even a "why."

With full recognition of the present-day limitations of science, the writer will attempt to define the two words which stand at the head of this chapter. An animal is "a system of activities"—a coördinated, individualized system of activities which is taking place in a particular mass of matter. This systematic series of activities must continually take place or the animal ceases to be. If coördination fails, the result is disorder and death. Each system has its own individuality and this is the basis for its order, family, genus, species and personality. Perhaps an animal is more than a body of matter and energy—acting and interacting, within and without. This science cannot determine—its

duty is to weigh and measure and it cannot express an opinion on anything that is metaphysical—*i.e.* beyond weighing and measuring.

The environment is all that surrounds an animal. It is the little world in which each animal maintains its activity and individuality. A system of activities which is continually changing thus lives in a changeful environment. There must be continual minor adjustments if the animal is to continue to exist.

ADAPTATION

Everyone knows that animals fit the environment in which they live. A carp is suited to water. It has gills for breathing and these are essentially on the outside of the body where they have direct contact with the surrounding water. A carp has a "stream line" form which enables it to make progress readily through the watery medium in which it lives. Its fins are flat and serve as effective oars for moving it about. Its organs of taste are scattered about more or less on the outside of its body. A kangaroo has the same fundamental plan of structure as a carp, but is adapted to life on land. It breathes by means of lungs within its body. It stands more or less upright so that its eyes

can see out over the surrounding country. Its legs are long and slender and it can progress rapidly by making leaps through the comparatively rare airy medium in which it lives. Its organs of taste are wholly within its mouth, where they can discriminate substances which enter from the outside and are at the same time protected from drying out. All animals are adapted, often in a very precise way, to the environment in which they live. For example, a flounder which rests on the bottom of the ocean changes its skin so that its coloration and pattern closely match the background upon which it rests.

Henderson has pointed out that, not only are animals fit for the environment, but the earth environment is such that it is especially fitted for the types of animals that exist today. In his works on "The Fitness of the Environment" and "The Order of Nature" he calls attention to the fact that the earth at ordinary temperature furnishes a place where the development of living things would be expected. Carbon has remarkable ability to combine with a number of other elements and this ability makes possible the endless variety of organic compounds. Water as a practically universal solvent and in association

with carbon compounds serves as a dilutant, distributor, and regulator. The compounds of nitrogen and carbon furnish the basis for protein materials from which living substance is largely built. It is fortunate that the range of earth temperatures is such that water may occur as ice, liquid, or vapor. If the temperature of the earth was 200°C. higher, life as it exists today would not be possible. Many factors contribute to make the earth a favorable environment for animals.

While there is no doubt that animals are adapted to environment, there has been much discussion as to how they have become so. There are two apparent possibilities: (1) animals are adapted because their system of activities happens to be able to exist in conditions as they are on the earth today or (2) the environment may cause animals to change so that they become adjusted to existing conditions. The question is, do animals change so as to fit the environment as it changes? This will be discussed in the next section.

To a scientist the word adaptation is merely descriptive. It means that an animal does fit its environment, but has no implication that environment by changing has caused an animal to change so as to fit better.

ADJUSTMENT

When a particular environment is changing, an animal which lives in it has three alternatives: (1) its system of activities may be transformed to fit the new conditions, (2) it may migrate to another part of the earth where conditions resemble those to which it has been accustomed, or (3) it may cease to exist. If some individuals of a particular species are forced to take the last alternative, the representatives of the species that survive may do so because they accidentally have individual peculiarities which permit them to continue to exist. There are always variations among groups of individuals, and when environment changes there may be a "natural selection" of a group of individuals that are adapted. This is the "survival of the fittest."

There are many animals that change with changing conditions. The little brine shrimp, *Artemia salina*, which lives in salty lakes and salt vats, changes its form as the salinity of the water varies and is adapted to its medium in all concentrations. If there is little salt, long appendages are developed for swimming. As the water becomes more saline, and consequently denser, the body becomes stouter and the appendages smaller. There are also many microscopic

animals in lakes which change their forms with the seasons each year. In cold weather, when the water is viscous and has greater buoyancy, they are stout; but in summer, when the water is less dense, and less buoyant, they grow more slender, and lengthy appendages, which impede sinking, grow out from their bodies. Many animals hibernate in winter, or aestivate in summer. They are thus able to pass through unfavorable seasons in a torpid state and assume their full degree of activity when the environment becomes favorable.

Among animals which migrate annually from unfavorable to favorable situations certain birds and mammals are perhaps best known. The arctic tern moves nearly from pole to pole and lives in perennial light. In the Northern Hemisphere many birds move northward to find desirable nesting sites in summer and go south again to spend the winter. Seals swim to their breeding ground in spring and scatter over the ocean after their young are reared. The arctic caribou moves in vast herds as the season changes.

Though it is easy to find samples of animals which show striking degrees of adjustment to changing environments, there are rather definite

limitations for each species. If the environment changes too much a particular species may become completely extinct. However, if environmental changes are rhythmical animals readily become adjusted to them, whether the rhythms be annual, monthly, or daily. All living things show rhythmical activities. Periods of activity and destruction of the living machine alternate with periods of rest and rebuilding. Many animals regularly pass through an annual cycle in which offspring are produced when the temperature is high, food is abundant and, later, when temperatures are low and food is scarce, there is more or less complete cessation of activity or a migration to a different locality.

The lunar cycle produces profound differences in the tides along ocean beaches and certain animals show striking adjustments to such variations. There are some species of worms which always spawn at high tide during the dark phase of the moon, when conditions are most favorable for the development of their eggs. Perhaps the most remarkable instance of adjustment to lunar rhythms is shown by the breeding habits of the grunion, a small smelt which lives along the coast of California. This fish spawns on dark nights, when the moon is full but not

above the horizon, on the second, third and fourth nights after the highest tides in April. Exactly at high tide it wriggles out on the sloping beach above the water. The females bury their posterior ends in the sand and deposit their eggs two to six inches below the surface. Each female is attended by a male which fertilizes her eggs. In the sand the packet of eggs is protected from enemies, and is able to endure rains and some degree of drying. Two weeks after the eggs were laid, when the changing phases of the moon again bring high tides, they are washed out of the sand and hatch. Any which fail to be dislodged may remain another fortnight without injury. If the grunion should try to spawn when the high tide came in the day, it would be eaten by gulls. If it should spawn just before the highest tides, when the beaches are being eroded, the eggs would be quickly washed away. But it deposits its eggs when the tides are still high and when the beaches are being built up.

Everyone knows of daily rhythms among animals. Some sleep at night and are active during the day; others, like bats, are active at night and go to sleep when the sun rises. Along the coast of England there is a small shrimp; *Hippolyte varians*, which changes its colors every

twelve hours. At night it is green but during the day its colors and patterns closely match the background on which it rests. In the ocean and in freshwater lakes there are many small animals which come to or near the surface at night, but descend, sometimes to depths of several hundreds of feet, during the day. There are countless daily rhythms in nature.

When an environment passes through a series of progressive, non-rhythmical, changes and is thus transformed into a new type, animals are apparently not able to adjust themselves sufficiently to keep pace with it. Their powers of adjustment are always limited. The species which were present at the beginning die and are replaced by others which are adapted to the new conditions. Suppose for example that the surface level of a large lake is gradually falling and that a small pond is thus left along its margin. At first this pond will have a clean, bare bottom and will contain the same species of fishes as the large lake of which it was formerly a part. But, as aquatic plants invade the pond from its margins, and as mud covers its bottom, the fishes of the open lake die and new species of fishes take their places. Winds and rains fill the pond with more muddy sediment and plants which

extend above the water grow farther and farther from the shore. There comes a day when there is no pond left, but a swamp has taken its place and now there are species of swamp fishes. Finally the swamp becomes a meadow and there are no fishes.

The foregoing discussion of course suggests the relation of adjustment to the evolution of animals. This will be considered more fully in Chapter IV.

THE EXIGENCIES OF LIFE

An animal that continues to maintain its system of activities must obtain certain things from its environment. If these are not available, the environment is not one to which the animal is adapted. The great exigencies of life are food, energy, safety, and the opportunity for reproduction.

Food furnishes materials for building the bodies of animals. It is also transformed so as to produce energy which is used in doing work. Animals differ greatly in their food requirements —both as to quantity and quality. There is a little protozoan, *Didinium nasutum*, which lives by engulfing its fellow protozoans *in toto*. It can swallow another animal which is ten times as

large as itself and in three or four hours is ready to eat again. This protozoan lives at a rapid rate and requires much food. On the other hand, certain ticks can exist in an active state for as long as four years without eating anything. There are animals which require a varied diet and others which can subsist on a very monotonous one. Some sea cucumbers eat nothing but mud. They pass enormous quantities of food through their alimentary canals daily. The clothes moth lives wholly on the keratin which composes wool. This is for most animals quite indigestible. It contains little or no water, but the clothes moth transforms it in such a way as to obtain water for its internal bodily processes. A man requires a varied diet which contains body-builders, energy-producers, and vitamines. Various diseases are known, such as pellagra, beri-beri, and rickets, which are due largely or wholly to deficiencies in diet. Man requires certain amino-acids and protein foods in order to build body substance. Among these tryptophane appears to be quite essential. If some nearly related protein compound is substituted for it in the dietary, normal growth does not take place.

The energy which animals continually require

is obtained in part by the transformation of the food they eat and in part directly from the sun and other bodies as heat and light. Some animals must apparently have energy from various sources, but others, such as those that burrow beneath the soil or live in caves, can flourish when their energy is derived largely or wholly from their food.

Safety from enemies which may injure or destroy and from extreme changes in environmental conditions is of course essential for all animals. If an animal is adapted to its environment, it has certain peculiarities in its own body which enable it to resist such dangers. The skin of a mammal is impervious to most solutions which might injure structures within the body. The tissues have their power of producing antitoxins which neutralize the poisons produced by invading bacteria.

Reproduction is necessary in order that a species may continue to occupy an environment generation after generation. There are two types of reproduction, sexual and asexual, which serve quite different functions. In sexual reproduction there is always a fusion of parts from two pre-existing individuals. As these blend into an unified whole and thus produce a new indi-

vidual, there is an opportunity for mixing and rearrangement of hereditary qualities from both parents. A new individual may therefore possess characteristics which make it better fitted for a changed environment. Asexual reproduction does not involve the mixing of qualities from two parents. It often occurs among animals when there is an opportunity for rapid multiplication of individuals in a favorable environment, as when food is abundant and temperatures are near the optimum. In some species of animals there are quite remarkable adjustments of reproduction to environment. There may be very complicated life histories with sexual reproduction at certain periods and asexual at others. Many plant lice vary their types of reproduction with the seasons. In summer only wingless females are present and these give birth to young which hatch within the bodies of their mothers from eggs which are never fertilized by males. After several generations of this type winged male individuals are produced and with their advent a new type of reproduction occurs. The females which are associated with the males are also winged and produce thick-shelled eggs which are able to resist the cooler weather of autumn and winter. In spring wingless females again appear.

CHAPTER II

Where Animals Live

The three great earth environments—ocean, freshwater and land—differ in stability, in the availability of water and gases, in the presence of particular salts, and in other respects. The pull of gravity makes all fluids denser toward the center of the earth and this leads to more or less stratification. The air and all bodies of water are therefore arranged in zones, or layers, from the center outward. Such stratification has a profound effect on the earth as a dwelling place for animals.

The earliest evidence that is preserved in the sedimentary, stratified rocks on the earth indicates that at first all animals lived in the ocean. This was perhaps two billion years ago. As time went by there was a gradual invasion of freshwater and land. Today animals have spread to all available parts of the earth and some have even taken to the air, but many freshwater and land animals show relationships to their ancestral home. For example, certain species of land crabs reside far from the ocean and even climb to the tops of mountains, but once each

year they return to the sea shore to breed; the young hatch in the sea and spend a few days as active swimmers. The liquids which flow through the vessels within some marine animals today are identical in composition with the medium in which such animals live. Even the blood of man has been called modified sea water. There is, of course, a great difference between sea water and human blood, but it is not improbable that the latter has been derived from the former.

THE OCEAN

The ocean constitutes about seventy-two per cent of the surface of the earth. It is on the whole the most stable and the most uniform of environments. This is partly on account of its vast extent and the free intercommunication between all its parts and partly because it is composed of water, which has the inherent quality of absorbing and losing heat slowly (one-fourth as fast as the land) and hence has considerable thermal stability. The ocean contains about thirty-five per cent of salt and at all depths there is enough oxygen for the respiration of marine animals. The stratification of the ocean of course affects its temperature and the water grows gradually colder as depth increases.

Particular localities, however, are rather uniform at all seasons. Minimum temperatures vary between −2.22°C. and −16.7°C.; maximum, between 26.67°C. and 32°C. Below about six hundred feet the ocean is below 2.5°C. the year round.

The food of marine animals, like that of all others, is derived directly or indirectly from plants. There are a few plants alongshore but the bulk of the food resources is in the microscopic plants which float in the open sea. The manufacture of food by green plants is dependent on energy from the sun, so such plants cannot live below the greatest depth to which light penetrates. Nitrates and nitrites are the usual sources of available nitrogen, which is essential for the building of the proteins in living substance. These salts are more abundant near the shores of the ocean; indeed they appear to be derived largely from the nitrogen-fixing bacteria in the soil; hence there are more animals near land than in the open sea. In ancient times there was probably more of lime and less of sodium chloride. Today the latter makes up about four-fifths of the salts in the ocean. In the different regions of the ocean various animals are adjusted to existing conditions.

The shores are the most variable regions in the sea. Tides and waves sweep over them; the shoreline is often rocky on headlands but changes to sand or mud at the heads of bays; rivers bring in freshwater and sediment; the temperature of the water varies somewhat at different seasons. On rocky shores most of the animals are firmly attached and tend to have a radial type of symmetry with the mouth at the center of the body. They depend for food largely on the microscopic animals and plants brought in by the tides. Often the animals on rocky shores are protected by limy or horny envelopes so that they are not easily injured and do not dry out when they are left out of water by a falling tide. On sandy beaches animals must burrow in the shifting bottom or swim. None is permanently attached. Most of these animals have some special means for keeping particles of sand out of their respiratory organs. Some clams bear long breathing tubes which they protrude above the sand; certain crustaceans have elaborate mechanisms for keeping their respiratory chambers clean. The food here, again, consists largely of the small animals and plants which come in with the tides. Over muddy beaches the water is comparatively quiet

and large plants are more abundant than on rocks or sand. The eel grass harbors many animals; others live in the mud or swim in the water above. Of course all burrowers must have special means for respiration. In this connection the "long neck" clam (*Mya*) is noteworthy. It has a breathing tube which is several times as long as its body. The colors of shore animals may show varied hues and patterns. On all ocean beaches many scavengers, both from the ocean and from the land, feed along the drift line, where flotsam is left by high tides. Here beetles and rats compete with crabs and other marine animals for food.

In the open ocean most animals and plants are small and transparent. They often contain drops of oil or bubbles of gas, and have long projections, which impede sinking, extending out from their bodies. Many of these animals avoid the surface of the ocean during the day but swim up to it at night. There are a few large animals such as jellyfishes, squids, flyingfishes, and whales which feed on the small creatures. Some of the animals at intermediate depths are luminescent and certain of these also swim at the surface at night.

In the deeper parts of the ocean the bottom

consists of soft mud, ooze, or of fine red clay. Here the animals live in darkness and under great pressure. Gigantic red crustaceans sprawl out over the ooze; sea pens and crinoids stand above the bottom supported by their stalks; black fishes swim about. These animals have no patterns, but dull colors which blend with the monotonous bottom. As there is no light, deep sea animals depend wholly on regions above for food. They live slow, sluggish lives and subsist on mud or other animals.

The ocean is in many respects a favorable environment. Animals living in sea water are continually surrounded by a medium which is quite similar to their own body fluids. The blood of many marine animals is like sea water in its salt content and osmotic pressure. The blood of marine fishes, snakes, turtles and mammals resembles sea water less closely but still shows a general similarity to it. The ocean has a relatively constant temperature and gaseous content. It is a solution of the chemicals from which living substance is readily built up. Some animals, such as whales, sea snakes, and turtles, and a few insects, apparently returned to the ocean after they had attained land life. Probably this was to take advantage of the continual and

abundant supplies of food and the general stability.

FRESHWATER

Freshwater animals came directly or indirectly from marine ancestors. In order to permit a change from salt to freshwater the permeable membranes on the outsides of animals must resist the passage of salts from the body fluids into the surrounding medium, or the animals must be able to endure a reduction in the salts in their body fluids. Some animals which live today are able to swim freely back and forth from fresh to salt water, but many whole groups of sea forms have never been able to invade even the estuaries of rivers. The salts in the internal fluids of the little killifish (*Fundulus*) do not change materially when it swims from the ocean into a river, but those in the blood of certain crabs may vary from 1.5 to 3.5 per cent with changes in the surrounding water. On the whole freshwater animals show less variety than those in the ocean. They live in an environment which occupies comparatively little of the earth's surface and which varies greatly in temperature, dissolved salts, oxygen and carbon dioxide.

In freshwater carbon dioxide perhaps plays

a more important rôle than in the sea or on land. In some situations, such as shallow swamps or the depths of lakes, there is a more or less complete lack of oxygen at certain seasons. This condition is associated with an abundance of carbon dioxide and the water may therefore have an acid reaction. Sometimes the amount of food that a body of water can produce is limited by the available carbon dioxide present, for this gas is essential for the manufacture of organic substances by green plants. Some plants are so avid for carbon dioxide that they will break up loosely combined carbonates in order to secure it.

Freshwater furnishes a variety of habitats for animals. There are perhaps three great natural divisions of these: (1) springs, brooks, and rivers, which flow toward the sea; (2) lakes and ponds, which are more or less stagnant; and (3) swamps and pools, in which the amount of water varies greatly with the seasons.

Streams all have the common quality of flowing water. They may be classified according to size, temperature, rate of flow, and character of bottom. Springs have rather uniform temperatures at all seasons of the year and therefore frequently serve as refuges for certain animals

when conditions are unfavorable elsewhere. For example frogs often come from the land to hibernate in springs. Brooks are swift-flowing, small streams. The immature stages of certain aquatic insects (caddis-flies, may-flies, black-flies) and trout are characteristic of such situations. Brook insects are adjusted to well aerated water and cannot live elsewhere. Where there are waterfalls such birds as the water ouzel build nests. Certain insects cling to the rocks in the swiftest water, which brings them food. Some brook caddis-fly larvae spin little nets from which they scrape accumulated food. Creeks are slow-moving and have muddy bottoms. Bullheads, breams, certain minnows, many insect larvae, and certain snails are characteristic residents. Large rivers are usually full of muddy sediment. They contain comparatively little food, except in the bottom mud, but serve as highways for fishes which migrate through them from one feeding ground to another. Heavy-bodied clams, which are not easily carried away by strong currents, large fishes (carp, sturgeon, gar), crocodiles, and turtles are typical river animals. Some of the river fishes (buffalo, etc.) breed only when the water rises and flows over adjacent bottom lands. If the river fails to rise in a certain year, these fishes do not spawn.

Lakes and ponds are bodies of standing water. They are much alike, but the former are larger and may contain peculiar types in their deep waters, as does the ocean. Ponds are shallow and their animals belong largely to the shore. They undergo rather extreme changes in temperature at different seasons and are stirred from top to bottom when the wind blows. In them live carp, sunfishes, bass and other animals. True lakes have sufficient depth so that they tend to stratify. In summer a warm stratum is established at the surface. When the wind blows, it may circulate the water in this but does not affect that below. The deeper body of the water is thus cut off from contact with the atmosphere from spring until autumn and in some lakes is wholly without oxygen for two or three months. In spring and autumn the temperature of deep lakes becomes uniform throughout and the water then circulates from top to bottom. In very large and deep lakes, the temperature at the bottom never rises above 4° to 5°C. and oxygen is present in varying amounts at all seasons. In such lakes animals that are related to those in the ocean may exist. Among these the ciscoes, which belong to the herring family, and certain crustaceans (*Mysis*, *Pontoporeia*)

may be mentioned. In Europe and America such relict animals are believed to have migrated along the borders of glaciers in days gone by and are now left inland only in the cool depths of lakes. There are a few peculiar snails, insects, and other animals which live in the deepest parts of lakes, but all these appear to have been derived in comparatively recent times from the local shore fauna. In lakes of intermediate size all the oxygen may be absent from the deep water throughout the summer. The fishes and some of the other animals are therefore obliged to move into shallow water, but certain of the fishes make brief excursions down into the stagnant region to snatch up food. Some of the animals (clams) which remain in the region without oxygen are quite inactive, and some (*Corethra*) migrate at intervals into the surface stratum and secure a supply of oxygen. There are several types of animals (chironomid larvae, protozoans, etc.), however, which are able to remain active in the absence of oxygen for two or three months. How they do this no one knows. The shallow waters of ponds and lakes support a great variety of plants and animals which vary with the type of bottom, degree of exposure to winds and waves, and the latitude.

In swamps and pools the amount of water varies and at certain seasons may be absent altogether. Swamps are largely or wholly filled with emergent vegetation. Pools contain considerable areas of open water. Many animals frequent swamps because the soft muddy bottoms render them inaccessible to predaceous enemies from the land. Blackbirds and wrens find safe nesting sites. Rails, coots, grebes, and certain ducks are typical swamp birds. Muskrats are also at home in such places. Small animals, such as aquatic insects, snails, and worms are often abundant. There may be fishes in swamps, but the decay of organic materials and the shallowness of the water often cause a lack of oxygen, and fishes are then absent. However, there are certain swamp fishes which are able to gulp in air from the surface and are thus able to persist in very stagnant water. There are others which can live without water for months, surrounded by a cocoon of slime and mud and buried in comparatively dry soil. Pools contain a variety of small animals which can stand drying. Some of these creatures become torpid and are encapsuled in cysts or cocoons during the dry season. Others die when the water dries up and leave their eggs to hatch when it comes again.

The eggs of certain phyllopods which live in temporary pools will not hatch unless they have been dried and subjected to low and high temperatures. From swamps and pools certain land animals probably had their origin. Lack of water and oxygen perhaps led to air breathing and development of the ability to live for a longer or a shorter time in or on the soil without drying up.

LAND

Land animals live in air, which is a much rarer medium than water and therefore permits more rapid locomotion. As speed is one of the primary characteristics of land animals they have come to depend more on sight than their aquatic ancestors. This enables them more readily to avoid objects and to leap on their prey from a distance with greater assurance. They enjoy an abundance of light, which of course favors the use of vision rather than other senses. Land animals also live in a medium that has a rather constant and high percentage of oxygen and this makes more rapid living possible. They must, however, endure the wide variations in temperature which occur on land (−45°C. to +50°C.), and low temperatures

usually slow down their rate of living and activity. They are often in danger of death from desiccation and must live where they can secure a continual supply of water.

Land animals have all come into existence since the oldest sedimentary rocks were laid down on the earth. Only a few types have been able to travel the long route from ocean to land: the worms, which have mostly remained within the shelter of the soil; a few snails, which already in the ocean had some protection against loss of water in their slimy coating and calcareous shell; the arthropods (crustaceans, spiders, centipedes, insects, etc.), which all possess a protective outside armor, or exoskeleton, of chitin, and the vertebrates (a few fishes; many amphibians, reptiles, birds, mammals), which are covered with a more or less impervious outside skin. Some of the migrants traveled directly through the tidal zone from sea to land (crabs, certain snails and fishes); others first became adjusted to freshwater and later attained the land (certain snails, the fish-like animals which gave rise to most of the land vertebrates). Some were perhaps driven out of marshes and swamps by lack of oxygen; some ran up the beach to evade marine enemies; some left the

ocean to avoid competition; some came to feed along the drift line and remained hidden under rubbish when the tide ebbed; some were left on land when swamps and pools dried up. There are many animals today which are partly adjusted to terrestrial life.

Of the animals which have attained land life, the most primitive live in the soil, especially where it is moist. They are thus protected from loss of water and from sudden and extreme changes in temperature. Most subterranean animals are cylindrical in form and have special organs of some sort for digging. They are of course dependent on the surface for food, because green plants and light are essential for the production of organic foods. An earthworm eats its way through the soil and at night pulls leaves into its burrow from the surface. A mole digs long galleries in its search for worms, insects, and vegetation. A pocket gopher comes near the surface, digs about the roots of a plant and pulls it down into its burrow.

The surface of the soil offers little shelter, and most of the animals that live on it are also associated with vegetation or live in burrows. The surface furnishes a highway for many animals which journey to and from other situa-

tions. There are, however, some animals, such as certain ants, spiders, lizards, birds and mammals, which habitually carry on their activities on the surface of the soil. The common rabbit, for example, is born, lives, rears its young, and dies there. Many surface animals are fleet and have colors which closely match the backgrounds on which they usually rest.

Land vegetation furnishes many types of homes for animals. It supplies food and shelter, and conserves and stores water. Desert animals get most of their water from plants. On steppes and prairies, the short grass shelters many insects and supports larger animals, such as hares, buffaloes, antelopes, and birds. Some prairie animals (marmots, gophers, owls, and snakes) spend much of their time underground. They thus escape strong winds and predaceous enemies. Forests support a great variety of animals. There are types especially fitted for life on the trunks of trees or among the leaves in the tree tops. Decaying logs and stumps give animals breeding places, shelter, and food. Termites eat nothing but wood. Woodpeckers and squirrels build their homes in it. There are many other associations between land and plants and animals. Certain of these will be discussed more fully in the next chapter.

There are no animals that live permanently in the air, but there are many that spend most of their active life there. A buzzard or a kite can soar for several hours without flapping its wings. Flying animals move at such speed that they require keen vision. Aerial life gives animals the ability to escape many enemies, to secure foods which would otherwise be inaccessible, and to make use of homes and nesting sites which are safe from molestation. Any animal which takes to the air must be well insulated to prevent loss of water and heat. It must have sharp vision, great agility, and special mechanisms for maintaining rigidity and making progress through air—the rarest medium in which animals live.

A few animals have evaded the extreme variations which are characteristic of the free atmosphere by resorting to caves, where conditions are remarkably uniform throughout the year. A cave bat may go to the entrance of its retreat many times, but never emerges into the outer air if it is too warm or too cold. Animals which live permanently in caves are often more or less degenerate, eyeless, sluggish, feeding on organic refuse or patiently waiting long hours for rare chances to catch prey.

CONCLUSIONS

All animals in all the varied realms and localities of the earth are adapted to the conditions in which they exist—to the environment. The most primitive, or old-fashioned, animals live in a stable, dependable, unvarying environment—the salty ocean. They are active in an unvarying medium which is much like the fluids in their own bodies. Marine animals are for the most part unprogressive and unintelligent.

Freshwater animals live in an environment which varies greatly in temperature, salinity, and gaseous content. They are usually in no danger of death from desiccation, but must make frequent adjustments to many pronounced environmental variations. Most of them live in a changeful environment and change with it.

On land animals are subjected to maximum variations in temperature and humidity. They live, however, in a plentiful and unvarying supply of oxygen and in a rare medium which permits rapid locomotion. Many land animals, like typically aquatic types, vary as the environment varies. When it is cold they live more slowly, or practically cease to live altogether;

when it is warm they can be active. Two groups of land animals, birds and mammals, have attained the finest expedient for life on land—homoiothermism. These keep the temperatures constant within their bodies by heat producing and cooling mechanisms. They are thus able to live always at a constant temperature and rate, at all seasons and year after year, and are therefore more or less independent of the environment. On the whole land animals are more progressive and intelligent than those in the ocean or in freshwater. At present they dominate the earth.

CHAPTER III

Interdependence of Plants and Animals

Since life began plants and animals have developed together. A plant and an animal are more or less interdependent. The activities of one result in waste products which are necessary for the syntheses of the other. Photosynthesis, the process which gives rise to nearly all the organic foods which are used by plants and animals, requires carbon dioxide which is, in turn, liberated by the breaking down of the substance of living or dead animals or plants. Decay is commonly brought about by bacteria and other fungi. All living substance forms carbon dioxide as a result of its activities. With a few exceptions, both plants and animals require a continual supply of oxygen, and oxygen is an end product of photosynthesis. Carbon dioxide in large amounts is injurious to living substance, and its presence may make a particular locality unfit for life. On the other hand, the fact that it is necessary for photosynthesis makes it a continual necessity for green plants.

Chlorophyll is the remarkable, life-supporting green substance which, when given a supply

of water and carbon-dioxide and energy in the form of light, can manufacture simple starches and sugars. These in turn can be built up by living things into simple protein substances if nitrogen and a few other chemical compounds are available. Although nitrogen makes up a large proportion of the atmosphere it cannot be used by living things in its simple, gaseous state, but must be combined with hydrogen, oxygen, and carbon before it can be made a part

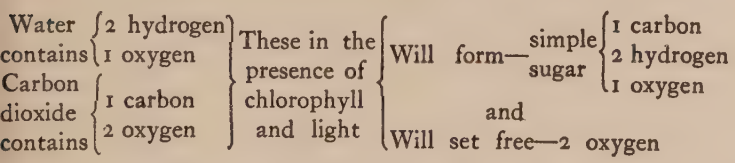
Water contains 2 hydrogen 1 oxygen
Carbon dioxide contains 1 carbon 2 oxygen
These in the presence of chlorophyll and light
Will form—simple sugar 1 carbon 2 hydrogen 1 oxygen
and
Will set free—2 oxygen

Fig. 1. The manufacture by plants of organic food from water and carbon dioxide.

of living substance. The only living things which are capable of combining gaseous nitrogen with hydrogen and carbon are certain bacteria, especially those which are usually found in soil and those often associated with the roots of leguminous plants, such as peas and beans.

Chlorophyll is not generally present in animals, but there are certain of the simplest of living things which can live either as plants or animals. For example, one microscopic or-

ganism, *Chlamydomonas*, when in light manufactures its own food by using the chlorophyll in its own body, but, if the same organism is kept continuously in the dark, it will lose its green color and die if it cannot devour organic food, such as bacteria or other minute things. Chlorophyll is not only essential as the machinery with which organic foods may be manufactured, but it is of great importance to animals in other ways. Some animals, such as certain protozoans, sponges, corals, and flatworms, contain small green plants within their bodies. These serve as little slaves which work to make food for their captors, and in turn receive protection and the essential materials for such synthetic activities. Chlorophyll is also known to be the source of pigments which serve important functions in animals. Even haemoglobin, which in blood is so essential for carrying oxygen to the tissues in man and other animals, is believed to be derived from the chlorophyll which is taken into the bodies of animals as food.

Plants, then, manufacture practically all the organic food in the world and animals must obtain it from them. They are also the chief factors, as bacteria and other fungi, in reconverting the bodies of dead plants and animals into

simple substances, such as water, carbon dioxide, and ammonia, which may again be used in the synthesis of foods. Somewhere in their substance plants also contain vitamines, which, though they occur in minute quantities, have lately been shown to be of vast importance for the proper nutrition of animals.

The dependence of animals on plants for organic foods brings about certain general relations between the two. Animals that eat plant food usually do not restrict their diet to particular species or parts of plants. However, some of them are very specific in their food preferences. For example, the boll weevil eats only cotton and the pronuba moth feeds on certain parts of the yucca flower. Animals that are non-specific in their food habits act more or less as regulators in nature. They tend to keep down the most abundant plants, which might otherwise become pestiferous. Vegetarian animals are of course always much more numerous in any district than the carnivorous species which prey upon them. There is a series of dependencies in regard to food. Plants must be present in sufficient numbers to support vegetarian animals without being seriously depleted; carnivores can never be so abundant as

to eat all the herbivores on which they depend for food. In any locality the plants and animals are so adjusted that their rates of growth and reproduction keep conditions fairly stable year after year. Without the influence of man there is seldom any over-grazing or famine.

Various animals have attempted to insure a stable food supply by storing food or raising crops. Certain ants, squirrels, beavers and other animals in times of plenty regularly gather appropriate foods which they store away for unfavorable seasons. The ancestors of ants appear to have been generally carnivorous, but certain desert species have gradually developed habits of gathering, husking, drying and storing the seeds of certain grasses. Other desert ants gather honey from flowers and store it away for use during the dry season in certain peculiar individuals of their worker caste. These remain within the nest, become greatly distended, and serve as living bottles for their fellows. Some species of termites make little beds of wood, the dead bodies of their comrades, and excrement. On these they plant and rear the fungi which they use as food. The leaf-cutter ants have progressed to an even more specialized type of agriculture. They go out along

beaten paths and bring home bits of leaves. Some of these they use to thatch over their nest, but others are chewed up and arranged in beds on which a peculiar type of fungus is grown. This is not eaten in its natural state, but is first carefully pruned with the mandibles of the ants. In this way peculiar growths, which were called "kohl-rabi clumps" by Muller, are produced. These growths constitute the sole food of leaf-cutters. When a young queen is ready to start a new nest she takes a little of the material from an old fungus bed and places it in a little pouch at the back of her mouth. She then makes her nuptial flight, breaks off her wings, digs a burrow, cuts a few leaves and prepares a little bed. Then she takes the fungus from the back of her mouth and plants it. She lays eggs and carefully rears a few young. When these mature, they begin to care for her and she then has nothing to do for the rest of her life but eat and lay eggs. Aside from a few insects, man is the only animal which has practised agriculture systematically. The relations of such activities as adjustments to environment will be discussed in Chapter V. The assurance of a continual and adequate food supply among insects and men has been important in making the development of social life possible.

Plants are important factors in regulating climate and in making conditions in any locality suitable for animals. They cover the bare soil and thus conserve moisture. When there is a growth of plants over an area, winds cannot dry out the soil so readily and deep-growing roots bring water to the surface. Water is continually lost through the leaves of plants and by its presence in the atmosphere tends to make temperatures more equable. During the heat of the day water evaporates and thus cools the air. At night its condensation gives up heat and its presence as vapor serves as a blanket which prevents radiation of heat from the earth. Thus when plants cover the soil they help to furnish water to keep air temperatures more uniform.

Plants continually shed leaves which fall to the surface of the soil below and serve as a ground cover. Such accumulations retard evaporation from the soil, prevent rapid changes in soil temperatures, and exert other useful functions. They furnish shelter and food for many animals and fungi. As they decay, they produce heat which may be taken advantage of by many animals. For example, the brush turkeys in Australia depend largely on the de-

cay of plant remains for the incubation of their eggs. These birds scratch together great piles of leaves and twigs and place their eggs within. They watch their rubbish heaps jealously and on warm, sunny days remove some of the material above their eggs, but during cold, wet weather they pile on more. Certain centipedes, salamanders, lizards, and insects take advantage of the heat generated by the decay of fallen logs to keep their eggs and young warm.

The vegetation cover over a tract of country also conserves and holds water in a more general way. The accumulation of living and dead roots, stems, and leaves, serves as a great sponge which retains water after rains. In various countries where forests and other vegetation have been thoughtlessly removed, disastrous floods have followed. Of course floods do not always result from denudation, but the removal of vegetation is perhaps the most important factor.

There are many remarkable relations between flowers and animals. Flowers offer various inducements to attract visitors. Bright colors and characteristic odors make them easy to find; rewards to visitors take the form of nectar, pollen, and other foods. In return for such favors animals carry pollen from one flower to

another and cross fertilization between different plants is thus insured. Some flowers show a high degree of adaptation for particular visitors. They furnish convenient landing stages, post color signals which indicate the shortest routes to the gifts of food, and have complicated entrances which prevent the stealing of offerings by unwelcome visitors. Some flowers depend largely on small birds for pollination and show corresponding adaptations. They are usually red in color and have long trumpet-shaped corollas. Other flowers possess special features which fit them for fertilization by bees, wasps, flies, butterflies, moths, beetles, or other animals. Avocado trees have two different types of blossoms on a single tree. The male flowers on a particular tree may open only in the morning, but on a nearby tree they open in the afternoon. On the same trees the female flowers will be open on the first in the afternoon and on the second in the morning. Insect visitors are thus pretty certain to carry pollen from one tree to another, and not between flowers on the same tree. The blooming of many flowers occurs at a particular time of day, and the insects which best carry their pollen are active at such hours but quiet at others. Flowers are often protected

from creeping marauders, such as ants, by having separate offerings of honey exposed below the flowers; by isolation in or above water; by sticky secretions; by slippery, smooth or waxy surfaces; and by other means.

Flowers have developed with animals. Millions of years ago there were no flowers. The first plants which crept from the ocean and freshwater on to land had none. Then plants began to develop pollen and seeds which contained stores of nourishment. The developing land animals soon took advantage of these concentrated and rich foods, especially during dry or cold periods when other foods were scanty. As animals formed habits of visiting particular plants, the latter gradually responded and various mutual benefits were derived from such associations. Finally the plants came quite generally to offer food, and advertised the fact; in return, animals carried pollen and distributed seeds. Fruits were developed which furnished luscious food about a hard or inedible seed. Today, a robin which swallows a cherry regurgigates the "stone", and thus these seeds are scattered about where they may find favorable places for growth. Burrs and little beggar-ticks take firm hold on the hairy coats of mammals and are widely distributed.

There are a variety of simple green plants, bacteria, and other fungi which live in the bodies of animals and serve various beneficial functions or cause diseases. Some of these aid in the digestion and assimilation of food. In fishes certain luminescent bacteria live in special cavities and produce light when stimulated by the host in which they reside. There are various fungi and bacteria which live in the skins of animals and cause diseases. In man these are most frequent in dark-skinned races. There are also bacteria which live within the body and cause diseases that are familiar to all: typhoid, typhus, cholera, tuberculosis, leprosy, influenza, etc.

Plants frequently furnish shelter or permanent homes for animals. The fibrous and woody portions of land plants are especially suited for such purposes. The paper-making wasps chew up fibers and shape them into nests which show characteristic forms and considerable architectural complexity. In the tropics bromeliads, which are all more or less like pineapple plants, harbor a great variety of animals, some of which are greatly flattened or otherwise especially adapted to live in the spaces between the leaves. Leaf-rollers, web-worms, and certain ants fasten

leaves together to make nests. There are even a few insects that habitually take shelter within pitcher plants, which entrap and devour most types of insects. Natural or artificial cavities in trees are used as homes by bees, beetles, woodpeckers, owls, hornbills, squirrels, and other animals. Wood, on account of its flexibility, strength and durability is an excellent material for the dwelling places of animals. It is also a good insulator and therefore protects animals against the extreme heat of summer and the cold of winter.

Among the most interesting of the relations between plants and animals are those furnished by ant plants. Most of these plants provide shelter and food for their guests and in turn the ants protect them from browsing animals and plant-eating insects. In America the ant plants are largely acacias and cecropias. The former usually have hollow thorns at the bases of the leaf-stalks. These serve as dwellings, and glands near the tips of the leaves furnish food. The ants which inhabit acacias are very pugnacious and have very potent stings. They drive away leaf-cutter ants and other enemies. The cecropias provide many small chambers for dwellings within their stems. They also supply food along

their leaf stalks, but many of their ants procure their food largely from plant lice which are kept in the chambers inside the stems. The ant plants in Asia are usually somewhat sponge-like, with intercommunicating spaces within a fleshy body and many small openings on the exterior. In British Guiana, Wheeler studied an ant plant which had about fifty species of animals associated with it. These included twenty-eight species of ants, besides beetles, crustaceans and other things.

The various associations between plants and animals not only show the interdependence between the two, but also add to the evidence presented in the two preceding chapters concerning the high degree of adaptation that all animals show to the particular environments in which they live. Animals are just as strikingly adapted to the living things which surround them as to the non-living. The next chapter will consider why and how animals are so adapted.

CHAPTER IV

Environment and Evolution

There is no doubt that particular environments limit the types of activities that may take place within them. A fish cannot carry on its daily routine in the tree tops and a swallow cannot find the exigencies of life in the depths of the ocean. Each environment restricts the activities of the animals in it to particular types, or patterns. This fact is more or less familiar to everyone, but the consideration of a couple of examples in some detail may make clearer the parts which environments play in controlling the types of plants and animals which can exist. For example, compare the animals which live on a rocky shore along the ocean with those which dwell in a tropical rain forest.

The animals on a rocky marine beach live in a continually changing environment. The tides ebb and flow; the winds exert a drying influence and roll in waves which pound upon the rocks; the blistering heat of summer alternates with the frigid blasts of winter; every rising tide floods the animals with cool water and every falling tide leaves them to swelter on the rocks,

exposed to the full strength of the sun. The incoming tide brings hungry and voracious fishes and the ebb exposes the beach to foraging gulls, rats, and crabs. The conditions of life on a rocky beach are hard. Yet one is surprised when he visits such a place to find that there is actually great competition for places to live. Barnacles adhere to the rocks as high as the tide reaches; groups of mussels are fastened to the rock in all the crevices; snails crawl back and forth, adhering firmly with their muscular, discoidal feet; anemones and little hydroids hold fast to the rocks beneath sheltering sea weeds or form veritable carpets in rocky pools. There are myriads of animals which take advantage of the abundant food in the form of microscopic plants and animals which every tide brings in from the open ocean.

On the rocks along the seashore, animals are quite apparently adapted to their environment. They are for the most part firmly attached so that they are not dislodged by the strongest waves. Many of them have stony outside shells to protect them from the beating of the waves, the drying action of the atmosphere, and extreme variations in temperature. The soft bodied anemones can endure drying in the air

for several days. If they are broken into pieces by blows from solid floating objects, each fragment of any size is able to reorganize itself and grow into a complete anemone again. Most of these beach animals are radially symmetrical, or tend to be so. When an animal is attached, it is of advantage to be able to receive stimuli or take food from any direction. Radial symmetry is inherently bound up with nervous decentralization. Animals which have their parts so arranged are therefore psychologically unprogressive and cannot reach a high mental state because their preceptive and action systems are more or less equally divided among all the points of the compass.

The animals on rock beaches have passed through a long evolutionary history to attain their present state. They are now adapted to their environment—sessile, armored, and radial. They are fitted to resist great variations in the environment, such as pounding and flowing movements in the watery medium around them; changes from air to water and from water to air; high and low temperatures. They are highly individualistic and compete with each other—even for space to live. They are sturdy to resist, but doomed to eternal stupidity. They hold on,

strain food from the water, and resist. Among such animals the barnacle is perhaps typical and its racial history may be surmised with some assurance from a study of its embryological and larval development. It apparently came from ancestors which lived a free life as swimmers in the ocean, which were bilaterally symmetrical and possessed eyes. When barnacles became attached by their heads, the eyes were lost, the swimming legs were converted into tiny fishing nets, and a calcareous shell grew up around the body. There was also a change from bilateral to radial symmetry. A certain security was attained by attachment but potentialities for higher psychic life were lost. In some respects an adult barnacle is degenerate when compared with its own larva. Certain types of barnacles are even more degenerate than those which live attached to rocks. There are some which live as guests in the gill chambers of crabs. Others (*Sacculina*, etc.) have become true parasites and as adults have no resemblance to their crustacean relatives. They consist of soft lumps, which contain genital organs, and of branching root-like processes, which penetrate to all parts of their hosts and absorb nourishment.

In a tropical rain forest, conditions for life

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are favorable. There is an abundance of food, shelter, and moisture. A great variety of animals live in the forest, but rarely is one found which is radially symmetrical. During past ages forest animals, like those on rock beaches, have evolved so that they are remarkably adjusted to their environment. Bilateral symmetry is generally associated with locomotion. An animal which has the parts of its body so arranged moves about with its anterior end ahead, and that end is provided with eyes and organs of taste, smell, and feeling. Such an animal is adjusted largely to the living things in its environment. It does not wait for things to be brought to it by winds or tides, but seeks actively for food, finds mates, flees from enemies, or pursues prey. Perhaps ants are as typical and ubiquitous as any animals in the forest. They are not individualistic, but are highly social. They coöperate, form armies and conduct forays, practice agriculture, keep domesticated animals and pets. An animal which skips about in the tree tops must have efficient sense organs. If it does not judge distances accurately, it may fall to the ground and meet a painful death. If it does not hear well, it may not find its prey or fail to escape from its enemies. Because animals in the forest are ad-

justed to living things, there is a premium on intelligence. One animal tries to outwit the other. Here in the forest the greatest thinker of the ages had his origin.

As on beaches and in forests, so it is in all other earthly environments. In the desert and on the prairie, in caves and on mountains animals are characteristically and appropriately adjusted. The environment dictates the styles, or patterns, of activity or behavior that animals may be permitted to assume. Does it cause animals to change to fit it? To some extent it does, but, as has already been pointed out in Chapter I, because there are limits to the adjustments animals can make, species become extinct and are replaced by others when there are fundamental and permanent changes in a particular environment. If a palaeontologist were to be asked what the commonest cause of extinction has been, he would probably answer "Too much specialization," or if he were a little careless even, "Over specialization." On countless occasions in the past species of animals have ceased to exist because their systems of activities could no longer persist in their environments. At times the climate became warmer or colder, more humid or drier, and some species died out.

Doubtless some types of animals became extinct on account of lack of food. A giant herbivorous dinosaur probably required a couple of tons of leaves and twigs for food each day, and when increasing aridity caused vegetation to become scanty some of the dinosaurs became extinct. Probably many species were exterminated by enemies, parasites, or disease. Fossil tse-tse flies are known from North America, and it has been suggested that such insects may have been an important factor in causing the horse to disappear from that continent. Some of the dinosaurs may have been eliminated by the small mammals which ate their eggs. Some species were unable to compete with new, and in a sense, better, types of animals which arose. The dinosaurs had smaller brains and were probably less astute than the early mammals; the flying reptiles for a time contested the air with the birds, but finally left the earth never to return.

There is general agreement among students of fossil animals that when a species became too highly specialized for a particular group of conditions which happened to exist on the earth, it was the one most likely to become extinct when there were unusual changes in environment. The dinosaurs became too big. The

flying reptiles were doubtless very agile and skillful flyers, but were probably never warm-blooded and were therefore obliged to become inactive during cold weather. The birds, however, could remain active throughout the year, and in this respect were better than their reptilian competitors. At the present time the house fly is less specialized in its food habits than the honey bee. The former feeds on a variety of foods and if one of these is absent it quickly turns to another. The bee is a specialist and is not only dependent on flowers for food, but requires particular types of flowers. If such flowers should become extinct, bees would cease to exist. Such is the price of specialization.

As the ages passed and environments changed, was there always a "survival of the fittest?" Not in every case. Survival was often a matter of accident for individuals. A tornado might kill all exposed animals and spare all those which happened to be resting in safe nooks. Such survivals had little relation to general fitness or lack of fitness to existing conditions, unless tornadoes occurred often enough to constitute a regular feature of the environment. No animal is perfectly adjusted to its environment. If animals were so adjusted, all individuals would

continue to exist. On the whole the fittest survive. But what is "fit" in this year, or in this century, or in this million years, may be unfit during the next period of time if the environment changes. A species which becomes so accurately fitted into an environmental groove that it cannot change is in danger of extinction. An animal if it is to survive long should fit the present but at the same time retain enough plasticity so that it can change if necessary.

Have animals improved? Have they become better? Scientists generally object to such terms as "improved," "better," and "higher." All animals which exist or have existed at any particular period have fitted the environment, else they would have ceased to be. On the whole animals made progress as the ages went by. This does not mean that they necessarily fit the environment better, but that they gradually acquired more means for surviving. An insect is a better animal than a trilobite; amphibians are better than fishes, reptiles than amphibians, birds and mammals than reptiles. On the whole the second type mentioned in each case has greater powers of discriminating and judging changes in environment and more means of resisting or responding to such changes. To this extent

evolution has been progressive. Animals have become more fit by gradually acquiring more means for remaining fit and this has enabled them to live in more and more variable environments. Until animals possessed external membranes which resisted the loss of the essential salts from their body fluids, they could not live in fresh-water; until they had special means for conserving water within their bodies, they could not live on land. Until they had digestive cavities they could not swallow food; until they developed bulky tissues they had no excretory organs to eliminate body wastes. As bodies became more complicated there appeared sense organs controlling and correlating nervous mechanisms, consciousness, thought and reason.

Why do animals continually fit changing environments, and wherein lies their ability to evolve into new types of animals? Environment, heredity, and selection are all involved in such adjustments and changes. Perhaps the powers of adjustment that every individual animal possesses are also concerned. No two animals, even those born at the same time from the same parents, are identical. There is always individual variation and individual peculiarities may enable one animal barely to survive when

another dies on account of changes in environment. The qualities each animal possesses have come to it from its parents. Each time reproduction takes place there is a mixing and recombination in the offspring of hereditary characteristics from each parent. There are complicated mechanisms for the transmission and reassortment of hereditary qualities during the production of new individuals. While there may be an endless variety of rearrangements, there is little or no scientific evidence that new hereditary qualities are acquired by individuals. Animals which vary so that they happen to suit the existing environment survive more often than those which do not. There is thus "natural selection" of the fittest, but "fittest" does not necessarily mean "best."

Since life began it has never existed without an environment and no animal appears to have qualities which it does not inherit from its parents. An existing animal system of activities is the result of heredity, environment, selection, and adjustment. All four are continually present and continually interacting. Heredity transmits qualities truly from parent to offspring and by various mechanisms tends to keep species unvarying generation after generation.

The organism is continually active and the environment furnishes it the exigencies of life. Selection continually preserves the individuals which best fit the environment. Adjustment permits individuals to fit into environmental conditions better.

How can evolution take place? How can one species change so as to become a new species, and what parts do heredity, environment, selection and adjustment play? This brings up the problem of variation, which science has not yet wholly solved. How and why do animals vary?

Hereditary qualities are passed down from one generation to another with great fidelity. Parental characteristics are mixed and reassorted, but seldom modified. However, new types of individuals, mutants, occasionally appear and these have qualities that differ more or less from those possessed by either parent. In some cases such individuals are known to be produced by the cropping out, in the reassortment which takes place during reproduction, of characteristics which have been present but hidden for several generations. It is possible also that some of such new qualities, or mutations, are really new characteristics which are appearing for the first time. If this is true, and

at present it appears to be, perhaps mutations may be the means for the formation of new species from old. How or why mutations take place no one knows. If they represent new characteristics, they furnish a basis for the formation of new species by natural selection. Some animals appear to produce more different types of offspring when environmental conditions become unfavorable. Perhaps a changing environment may at times stimulate the formation of mutants.

Another possible means for the production of evolutionary changes is through the inherent powers of adjustment which all animals and plants possess. Organisms continually change their systems of activities to keep pace with variations in environment. They live rapidly or slowly; wear thick coats or thin; grow to be long and slender or short and stout; and make many other structural or physiological modifications. Many persons believe that such "acquired characters" (acquired by adjustment during the life of a single individual) change hereditary characteristics and, perhaps after many generations, produce new species. In this case environment would play an important rôle, for changes in it unquestionably cause adjustments. Un-

fortunately there is little or no scientific evidence which gives support to the idea of hereditary transmission of acquired characters.

Very early in the life of any individual its germinal, or reproductive, part is separated more or less from its soma, or body proper. The latter does the everyday work that the exigencies of life require of each individual as long as it lives, but there is practically no evidence that such work with its incidental adjustments exerts any influence on the hereditary qualities which the germinal part transmits to the next generation. The son of a blacksmith does not have strong and sinewy arms unless he works at forge and anvil like his father.

There is no very convincing evidence that environment causes evolutionary changes. It furnishes the medium in which such changes take place and dictates the patterns which systems of activities may take, but it does not appear to cause them. All science in its present state of knowledge is able to say is, (1) that evolution undoubtedly is taking and has taken place, (2) that new types of animals are at times (perhaps always) produced by mutation and that these may lead to the formation of new species, (3) that new types may be preserved by

natural selection, (4) that environment furnishes the medium in which evolution takes place and exerts control over the type of animals that may evolve. Variation in animals is not wholly understood and it is possible, (1) that it may take place wholly by chance, (2) that it may follow laws which are not affected by environmental changes, or (3) that it is influenced by environment, which may (a) cause new variants to appear, as a result of individual adjustment, or (b) stimulate the appearance of more types of variants after the reassortment of characters during reproduction.

CHAPTER V

Man and Environment

Man today proudly dominates the earth. He has so successfully adjusted himself to environment that he has outstripped all competitors. Never in his long struggle upward in the past or at the present time has he been or is he free from his environment. His civilization, culture, and all in which he takes pride depend upon environment. And his body bears many indications of what his relations with his surroundings have been in the past. The ancestors of man were apparently aquatic at some remote time—else why should the developing human embryo, in common with those of other vertebrate animals, always develop gills on the sides of its neck? These gills never function as breathing organs. Why should they be present? The accepted opinion among scientific men is that these organs are a survival from times when the ancestors of man lived in water and breathed as fishes do today. During ancient times the ancestors of man, like other early terrestrial animals, probably at first lacked proper insulation on the outsides of their bodies. Doubtless many of them

lost too much water from their interiors and died. But as time went on tough skins developed which held water in. Later these skins bore a covering of hair which served to conserve heat as well as water. Then constant bodily temperatures were developed within the bodies of such animals and these were maintained near the optima for living systems of activities by various controlling mechanisms. Given a constant bodily temperature, which permitted perennial activity, and a highly efficient brain, man has been able to make inventions which now enable him to lead the world. Yet he is an animal—an ever-changing system of activities living in a changeful environment.

The immediate ancestors of man were probably arboreal for a time. The only other animals which have prehensile hands and feet in which an opposable thumb or toe plays a leading rôle are monkeys and apes, which still live largely in trees. The only animals which have highly efficient bifocal vision are dwellers in tree tops and flying predators. Such animals must judge distances with great accuracy. If monkeys do not, their jumps from limb to limb may fall short and disasters result; if an owl mistakes the exact position of its prey, it may go hungry.

Man has bifocal vision which is as efficient as that of any of the primates. He probably acquired this when he lived in trees. The only other animals besides man which have flat nails are primates. The most primitive of these often have nails and claws on the same hand or foot. However, the true monkeys and apes have no claws; all their digits are armed with flat nails. Some baboons and tailless apes have left the trees more or less and often spend considerable time on the surface of the ground. In the remote past man apparently did the same. "Man may have evolved from his more humble beginnings on the partly wooded prairies of upland plateaus, where he had to use his wits and speed to pursue the agile game that lives in such regions and where he had a stock of good flints to use when the tool-making stage of his development arrived." Man did not arise from an ancestor which closely resembled any of the existing hairy apes. "The hands and arms of apes are developed with special reference to tree-climbing, and are in this respect more highly evolved than the relatively unspecialized hands and arms of man. .... The hand of man, with its exceedingly flexible fingers and opposable thumb, is an instrument of manipulation such as no ape or

other animal possesses. To reach its present state it must have been freed from the burden of tree climbing and from any other assistance in locomotion for many millenia; and this, Dr. Osborn argues, could have occurred only in a ground dwelling pre-human or early human stage ranging in a partly open region."

Man has long been a social animal. This is indicated by the most ancient of his fossil remains. Such a view is also supported by the lack of seasonal periodicity in his reproductive activities. Most animals breed at a particular season of the year but man does so at any time. This fact also suggests that man was not only social but lived for long ages in an environment which furnished a continual supply of food and perhaps showed a considerable degree of stability in regard to other environmental factors. Man in his civilized, social life has a greater degree of "time-binding" than any other type of animal. Not only are his homes and other works passed on from generation to generation, but his spoken and written languages make it possible for him to preserve his intellectual and spiritual attainments as well.

Perhaps the effects of environment on man are most apparent in what is commonly known as

climate. The earth is said to have different types of climates because there are variations in temperature, moisture, wind, light, and other environmental factors. Though it is "human nature" to long for stability, man is apparently not at his best in a monotonous climate. Nothing extraordinary develops in monotony. The great cities and the aggressive peoples of the earth are in temperate regions where the climate is variable. Where the conditions of life are severe, men expend most of their energies in barely living, but where there is an abundance of food and a climate which varies enough to stimulate man to activity, culture may reach an advanced state. On the wind-swept arctic barrens or on the Sahara Desert there are no great cities, factories, or universities. Though the Amazon Basin has bountiful supplies of food and an equable, moist, climate, it has not produced an outstanding civilization. The people there have been shown by physiological experiment to live at a slower rate than comparable men in temperate zones. While the scientific evidence is not very complete or conclusive, it indicates that the human race is not very productive in any hot climate, whether it be moist or dry. This lack of accomplishment is probably due largely to the

monotony of such climates but may obtain on account of other causes, such as prevalent diseases. Malaria, hookworm, yellow fever, plague and other diseases undoubtedly play an important rôle in retarding culture among tropical peoples. It is not certain that high temperature in itself is injurious to man and in a tropical climate there are many other factors to be considered. Strong sunlight is quite harmful to certain persons and if encountered day after day may cause a rather unusual type of anaemia. More should be known about the effects of tropical climate on various races. Dark-skinned peoples undoubtedly flourish better in the tropics than lighter races, but whether the generally lower levels of such peoples, in productivity and in culture, is due to climate, heredity, social customs, or other factors is not certain. The study of tropical countries is important because they offer great opportunities for the expansion of mankind into untilled and fertile areas. The writer believes that the tropics should be left largely to dark skinned and rather primitive races. These should be encouraged by financial aid, education, and the eradication of disease to develop their resources and contribute them to the world at large. Tropical countries should

perhaps be inhabited largely by simple-living peoples who will work for low wages and furnish such products as rubber, cacao, timber, and palm oil.

In all climates man has long attempted to keep the immediate environment of his body more or less uniform by wearing clothing, erecting wind breaks, and living in natural or artificial shelters. He has thus protected himself from extreme changes and been able to increase his productiveness because he was able to work without being interrupted by caprices of the weather. Modern city life is perhaps too monotonous. When people live in steam heated apartments where there is insufficient moisture and little variation they are apt to grow stale. Air which is warmed without being moistened dries out mucous membranes and paves the way for colds and chronic diseases. Tuberculosis flourishes among those who live indoors in dust and darkness.

Soil is an important factor in the lives of man. In the Great Lakes Region of North America, there is a large tract of territory known as the "Goiter Belt." Here many persons, especially young women, show enlarged thryoid glands. This condition comes about because the salts of

iodine have been leached out of the soil and carried to the sea by the rains of countless ages. There is therefore a lack of iodine in the plants grown in the soil and people in this district do not get enough of that element in their food. Such deficiency is commonly corrected to some extent by the use of iodized table salt. In the southeastern United States hookworm is quite prevalent, but on the dry, sandy soil in the Southwest, it is quite uncommon. In this case the character of the soil makes a profound difference in the lives of farmers in the two locations. In Nigeria all the soil for crops is broken by hand with hoes. In the southern part of that country the tse-tse flies are so prevalent and carry such virulent diseases that no horses or cattle can live; in the north there is so little rain that the soil never becomes moist enough to plow. The soil is the source of the bulk of the daily food of indigenous peoples in all parts of the earth. Its character determines the types of crops which may be successfully grown and these in turn influence the types of civilizations which may develop. Rice-eating peoples lead quite different lives from those which subsist largely on cassava or wheat. An inland prairie is usually thinly populated and is

devoted largely to grazing for large herds of big animals. A luxuriant forest near the sea is densely populated by men who fish, hunt, plant gardens, and raise small domesticated animals such as goats, chickens, and pigs. The daily life of man frequently depends to a considerable degree on the character of the soil.

As the environment furnishes the exigencies of life for man—food, shelter, and opportunities for producing offspring—he has an obligation to protect and conserve it so that it may continue to serve his needs and those of his progeny. Man by his presence is often able to modify the environment so that it becomes more favorable for him. On the other hand he has often carelessly destroyed his natural resources and his heirs have suffered in consequence. Timber lands have been ruthlessly cut over on many parts of the earth. It will be many years before such areas are again made productive through the application of scientific forestry. Lakes and rivers have frequently been so polluted with sewerage and factory wastes that the aquatic animals in them have died. The refuse from vessels in harbors has killed fishes alongshore. Sometimes man's activities produce remote effects which do not at once become apparent. There is a biological

balance among all the species of plants and animals in any region and a change in one species may produce unexpected effects in others. For example, the destruction of the coyote in the Wasatch Mountains in the northwestern United States caused an unusual increase in its common prey, the snowshoe rabbit. In winter this rabbit feeds on tender buds and twigs and as it became more numerous held back the growth of great areas of conifers for many years. Thus the destruction of the pestiferous coyote changed the whole aspect of the vegetation in the district. In Scotland the protection of gulls on a moor led to the growth of grass and dock and there was then a great decrease in the number of grouse. When, later, gulls were no longer protected, heather returned to the area and grouse again became common.

As conditions in any region are transformed from the primeval to those which accompany civilization, marked changes are of course to be expected in the plants and animals. Some species become extinct; others find dwelling places in farms and cities. Some decrease in number; others increase and become pests. There are certain weeds which vex every agriculturalist. These when a country was in a wild state per-

haps occupied an unimportant place among indigenous plants. There are many insects and other animals which destroy vegetation as an area is gradually occupied by man. They thus deplete food supplies and other resources. Many pests are foreign species which have been accidentally or intentionally introduced by thoughtless or well meaning but misguided persons who knew no better. Such plants or animals often increase very rapidly because the natural checks which would limit their numbers are not present. Everyone knows of the devastation caused by the gipsy moth, the cotton boll weevil, and the Argentine ant in the United States; the mongoose in Haiti; and the rabbit in Australia.

Domestic animals are a great asset to modern civilization. When the men of the Stone Age began to keep flocks and pets, their culture at once reached a higher level. These docile and loyal supporters of mankind have given companionship and comfort, aided in hunting, carried heavy burdens, and laid down their lives to furnish food. But their close association with the human race has brought it additional troubles. Domestic animals occupy space and require greater pastures to furnish them food. Perhaps they will as the earth becomes more

densely populated have to give place to machinery in order to make room for men. They also spread diseases. Cats carry tuberculosis; dogs bring ticks and fleas into houses; cattle spread typhoid, tapeworms, and tuberculosis; goat's milk is at times a source of fever; pigs are subject to dysentery and their flesh may contain the infective stages of tapeworms and trichina.

As particular environments set the patterns for evolution and influence the adjustments of animals, so they influence the cultural and social adjustments of man. The human race, like other groups of animals, rarely makes progress by throwing off all old types of adjustment, all habits and traditions, and leaping suddenly into a new environment, but usually advances by the slow modification of what already exists. When man changes his environment by adding to or substracting from it, he should do it thoughtfully, tentatively, and carefully. Governments in various countries have spent the money of taxpayers to drain swamps and thus valuable resources have at times been lost. Politicians supposed that more land meant more crops, more food, and more happiness for everyone. But all swamps are not alike and some are of more

value as such than as meadows. Some should be drained to rid localities of disease-carrying or pestiferous mosquitoes and others make fine farming land. However, there are some swamps which do not harbor pests and which will be of little value for agriculture if drained, but, as swamps, support waterfowl, fur-bearing animals, fishes, and aquatic plants. These in their natural state are great assests to hunters, trappers, fishermen, and those who seek recreation outdoors. One progressive government recently passed appropriations to "reclaim" certain areas back into swamps which had previously been drained by enthusiastic but misguided politicians. Man should be very careful about tampering with his environment. Before making any changes those in authority should consult scientists, artists, business men, priests, and any others who may have worth-while opinions on what the effects of such changes will be on the natural resources, health, and happiness of all concerned. Environment should be recognised as holding all the past and the future of man and treated with thoughtful consideration.

In the environment of modern man one of the most important factors is in the contacts which each individual has with other men like

himself—what is commonly called "society", but perhaps better "social life", because the former word carries certain invidious associations which are concerned with affairs that relate largely to style and fashion. Every society must have certain generally accepted customs, but these are only a few of many possible expedients for surviving by living together. The higher state of culture a society reaches, the more is originality penalized. A man living on a remote farm with a few companions might wear a tin pail for a hat without much trouble but if he tried to do this in a big city, he would be the subject of unfavorable attention continually. When a group of social customs have once been established by long evolution through countless ages it is very difficult to change them. Though such inertia is proper and essential, and though all members of a society must expect to observe established customs if they intend to succeed, each individual should remember that the end of social life is not to be like others and thus be accepted as a member of society. Social life enables man better to survive. It is one means of surviving and gaining the exigencies of life. But sometimes accepted customs become a burden and handicap a race in its competition with

others, which may even be less "cultured." The many "taboos" of the Hawaiians were a considerable factor in making them a decadent people. Many persons in modern society spend their whole lives in being like their fellows. They go to school and learn what others know and to think what others think; they attain maturity and with some effort learn to smoke cigarettes in order to show that they are red blooded men or women; they raise children and train them to be like themselves; they die and are buried according to accepted customs. Viewed from one angle society makes a pathetic spectacle. Its end is not to make all of its members conform to average standards, but it often operates so. It not only hangs murderers and restrains criminals, but burns Saint Joans and crucifies Christs.

Among animals societies always arise from families. Parents and children learn to observe certain customs and perhaps establish laws which enable them to live together in more or less peace and harmony. They gain the strength of unity and with numbers accomplish more than is possible for individuals. Relatives have a certain degree of fellow-feeling; clans and tribes grow by the association of families; nations arise from racial stocks which occupy suitable areas

of the earth's surface; leagues are formed to further the common interests of nations. Every animal has two chief instincts—(1) to compete with all others for the daily necessities of life and (2) to rear offspring. Thus each must strike a balance between selfishness and altruism. In a society every individual must defer to the needs and wishes of others. Thus individuality languishes. Furthermore, there is no society which does not foster parasites. There are always individuals which contribute little or nothing and live by the altruism of their fellows. Perhaps ants have developed the most specialized of societies and these are infested by swarms of non-productive or actually harmful individuals —beetles, wood lice, flies, wasps, ants, and other types of social parasites.

In modern human society there may be said to be three levels of personalities: parasites, average members of society, and leaders. The words "personality" and "character" are largely products of social life. A person of high character is one who fully understands social usages and observes them. He gets along with his fellows and is respected. A man with personality has certain anatomical, physiological, neurological, and psychological qualities which aver-

age up into something that is pleasing to his fellows and perhaps give them confidence in him. Ability is the power to accomplish things in the modern social environment. An able man usually has personality and character, but he may have many qualities which seem undesirable to his fellows and yet be an outstanding individual on account of the possession of an unusual degree of some particular quality, such as intellect or unusual sensory or muscular equipment, which makes him a genius. Abnormal personalities are found in prisons, universities, sanitariums, legislatures, asylums, and pulpits. What most men strive for is to be average, or normal, but at the same time outstanding. Man longs for fellowship and recognition. He attains the former most easily by being average—a common man. The great are often lonesome and unpopular, and subnormal personalities are often misfits in modern society because they lack ability. Supernormal or subnormal persons are perhaps most often unhappy. Suicide is less frequent among average citizens than among those who have too much or too little ability for the social environment in which they live.

Perhaps the best single tool with which to attain success in modern society is self-control.

A high-class, normal man is self-contained and well mannered. He is not impulsive, bigoted, nervous, partisan, or selfish. He is considerate, moderate, thoughtful, patient, deliberate, and judicial. He must work continually to near the limit of his abilities, but not incapacitate his living machine by over-effort. He must be senseful. Such a man does not eat too much; he does not buy things that he can not afford; he does not rise so fast that his colleagues become jealous; he does not marry before he is able to support a wife; he does not have more children than he can supply with food and keep in health. Self-control is of course the enemy of impulsiveness and therefore often inhibits spontaneity and originality. As Joad has well pointed out, continual self-control is tiresome. Man is often so bored by his social life that he revolts and gains a certain satisfaction from such outbursts. Furthermore the discoveries of science have given man greater ability but not greater wisdom. They have relieved man of the necessity of spending most of his time making a living and he has not yet learned what to do with his luxurious leisure, which is becoming an intolerable bore to him. Joad believes that man must acquire the ability to amuse himself with thought rather

than with awareness of material objects. He must go less to base ball games and occupy himself more with art, science, and mathematics. "In all civilizations those who have had the combined energy and opportunity to try every kind of life have been almost unanimous in asserting that the only thing which can give permanent satisfaction is the exercise of our best faculties at their highest pitch of intensity, alternating with the recreation of the mind in conversation and art and literature. That it will take centuries of boredom to convince men of the fact is undoubtedly true; the danger is that they will destroy themselves before they learn it." This is manifestly the opinion of a scholar. Does the salvation of the human race depend upon the attainment of universal scholarship and the enjoyment of it? The writer is not convinced that it does and believes that human civilization will go on to its end with a society which contains a heterogeneous group of people—some scholars, some unlearned and uninterested in learning.

Now for a brief consideration of that vexatious present-day question—the relation of the character, personality, and ability of man to heredity and environment. Every animal comes into existence in a particular environment to

which it is more or less adapted. Will such an animal, particularly a man, in an environment which is best suited to its system of activities be a better animal than if it is compelled to live in an environment to which it is ill-adapted? Better in this case is intended to mean more able.

An animal begins life with certain given abilities which it inherits from its parents. Reproduction permits the recombination and reorganization of parental qualities so that it is possible for an offspring to excel or fall below either or both its parents in any particular quality. The laws which govern the transmission of hereditary qualities are quite well understood, and, though science has still to fill in many details, the general scheme of the mechanisms of heredity is quite clear. During its life an animal can by the use of given abilities make certain adjustments to environment. Such adjustments appear always to have a rather definite range, which is determined by heredity. A dog can easily learn to know his master and can assimilate certain abstract ideas, but no dog has ever learned to solve problems in calculus and probably never will. Every man is also born with given potentialities, or abilities, which may to a certain degree be developed or suppressed by environment.

Among civilized men there are many primitive types of adjustment which resemble those of other animals. Man, however, has perfected the finest technique for adjustment through the opportunities afforded by his social life and his education. A modern man's responses to environment are to a considerable degree adjustments to social customs. The success of each individual depends to some extent on opportunity to obtain education in conventional methods of behavior in society and in part on ability to fit into social situations without friction or resentment. Learning in social technique, self-control, and ability are the tools of success.

Environment may keep a potentially great personality from fulfilling the possiblilities which it inherited from its parents. If such lack of opportunity is due to competition between individuals of unusual ability, society should progress to higher levels. But if society arbitrarily limits the activities of its members by careless and unwise caste-favoring and productivity-limiting customs or laws, unhappiness, dissatisfaction and anarchy result. Man, more than any other animal, can control the conditions in which he lives. Let him take thought as to how they may be kept fit. A proper environment must not

only supply the exigencies of life, so that man may live in comfort and safety, but also afford opportunities to encounter the variety, uncertainty, and struggle which gives spice and flavor to existence. A man who lives in assured monotony endures bovine contentment or bored discontent. One who ever strives to make his environment such that he always works to the limits of his powers continually increases his abilities. As years go by he takes on new and greater responsibilities; he becomes more powerful and exercises more and more control over his environment. He lives in greater ease and safety; he helps and gives employment to his fellow men; he passes laws and inaugurates customs which improve society and civilization. His fellows call him good and great. At times such a man wallows in the slough of despondency and at times he soars among the golden clouds of supreme happiness—those who struggle sometimes win and sometimes lose—but he has the continual satisfaction of having done his best.

Every man is born with a certain range of abilities or potentialities. Scientific evidence indicates that physical or social environments can increase or decrease these little or not at all during the life of an individual. But environ-

ment may determine the difference between a parasitic criminal and a productive genius. The administration of human society should involve the provision of such an environment that all children have opportunity to develop the best that is in them. But above all, every individual should himself never cease to strive to adjust himself and to change his environment so that he lives each day at a higher lever—more comfortable, more self-controlled, more capable, more understanding, more charitable, more far-reaching, more powerful.

Environment is not an inflexible mold which forces mankind into horrid and fantastic forms, but a plastic medium which furnishes the materials for making man ever more beautiful.

CHAPTER VI

Science, Commerce, and Religion

Present-day civilization is more or less upset by conflicts between old and new ideas. Commerce has established trade in all parts of the earth and no nation can remain aloof from contacts with new customs and standards of living. Science has given man new tools for carrying on the struggle for better and higher life. Religion is adapting itself to present-day needs. What of the relations between these three great interests of modern man?

Science has made steady progress in the discovery of truths relating to natural phenomena. Through its weighing and measuring, many of the miracles and mysteries of the past are understood. Events which in the Middle Ages were looked upon as acts of gods or devils are now weighed, measured, and predicted with assurance. The high regard which scientists have for truth, as determined by weighing and measuring, has made agnostics and there are now those who believe that there is nothing in the universe which cannot be weighed or measured. The materialism of the Seventeenth Century has re-

turned. Science has by its discoveries given man a dominant position. Nature is his servant. He lives in comfort, eats better food, is more or less free from disease, and enjoys improved methods of communication and travel. He is more powerful than ever before. However, the discoveries of science do not always improve civilization. The aeroplane not only carries mail and passengers swiftly, but is also a terrible engine for waging war. The radio broadcasts vulgar, low things as well as refined, elevating things. Pistols protect pioneers from the attacks of wild beasts and help robbers to injure their fellows. In his present state of evolution man apparently needs more than science to keep his world safe and orderly.

At its lowest level commerce is only an expedient for existing. Its aim is gain, and its ideal is greed. But at its best commerce is one of the great uplifting influences of civilization. It has broadened human knowledge by advertising and the development of new markets. It has increased international acquaintances through the dissemination of books, moving pictures, and other products. It has improved transportation and thus made travel and intercourse between different peoples easier. It has raised standards

of living throughout the world. The natives in "darkest" Africa now use enameled dishes and eat white bread. Through competition and improvement the necessities of life have become cheaper and all men therefore enjoy more of luxury, leisure, and knowledge. The joy and excitement of selling have been more and more supported by worthy pride in the products sold. Modern industrialism has enabled great minds to furnish dependable employment for many of their fellows in fields and in factories. Business geniuses have seen new opportunities and opened new markets, made martial or peaceful conquests of new territories, and taught better ways of living. Labor and capital have become important factors in modern civilization. Commerce tends to make society more stable. Revolutions usually spoil markets, lose jobs for laborers and money for capitalists, and bring society to a lower level. Commerce cherishes stability.

Man is a religious animal and has established countless religions. These engage to furnish their supporters more or less of comfort and happiness. Most of them take the form of the worship of a god, or gods. These deities appreciate such attention and reward the dutiful. There is no general agreement among religions as

to what or who god is, but such a supreme being is usually looked upon as a metaphysical personality who is omnipotent, wise, just, and appreciative, but at times intolerant. Religion has been a potent factor in the rise of man. It has been the usual medium for the promulgation of systems of ethics. Men are much more likely to accept commands from a deity than from a group of men, no matter how fair-minded and unselfish the latter may be. Most religions depend on more or less arbitrary creeds. These are of course essential because religions are man-made and there must be some general points of agreement in order to avoid a chaos of small groups. A man who is trained in youth to the observances of a particular creed develops a conscience which makes him unhappy if he does not live according to his religious ideals. Religion has given comfort to millions of people through the ages. Usually by revelations concerning the past, present, and future and promises of reward to the faithful and help in time of trouble, the followers of creeds have been led to steadfast faith in certain ideals and beliefs. The members of such groups have given each other companionship and aid. They have had moral support and gained satisfaction and happi-

ness by doing what their fellows deemed good and right. Religious faith has given inspiration to many men to be great. The Mayas, Egyptians, Buddhists, Mohammedans, and Christians built magnificent temples, mosques, and cathedrals. Bunyan wrote beautiful poems while suffering in prison. The early Christians allowed themselves to be burned and fed to lions by their Roman masters. The crusaders died singing hymns in Palestine. When a man is obeying the wishes of God and receiving the moral support of his fellows, he performs noble deeds.

When a particular creed has been successful and has gained many adherents, the administrators of it have often become so powerful that they have claimed to be the mouthpiece of God. If a church rules a nation and if the administrators are wise and honest, there is a good government. Men who are carrying out the direct commands of a deity have added confidence in their own powers and a "higher" reason for self-control than the irreligious or over-sophisticated. They are orderly, cheerful, and loyal. Their society runs smoothly. Religions begin when a great leader shows the people of his time how to live on a higher level. When an outstand-

ing personality can inspire a body of people with faith in new ideals, a religion is born.

What are to be the interactions between agnostic science, materialistic commerce, and faithful religion? Civilization is an operating institution with established organizations which represent each of these fields of human effort. No one of them can be discarded because it is not wholly in accord with another. The civilization of man will doubtless go down to its end supported on the shoulders of this great triumvirate. These three must, as their living and changeful burden twists and turns, make continual adjustments.

Theoretically science can never be wrong. It seeks only to learn the truth about natural phenomena by weighing and measuring. Unfortunately scientists are often wrong because, being human, they are at times bigoted, prejudiced, partisan, and untruthful in that they discover or disclose only the facts which please them. Furthermore, some scientists are regrettably conceited. Having discovered a few truths, they reach a fanatical psychological state in which they assert, like a devout Mohammedan—"There is no truth but our truth! There is nothing in the world that cannot be

weighed and measured." Perhaps this is true and perhaps it is not. It is unscientific to make such statements at the present time because there is insufficient evidence, and science rests on evidence. When a scientist says, "There is no god. Religion is unnecessary. Let us throw away such mediaeval trash,"—perhaps he is a thousand years ahead of his time; perhaps he is a conceited ass.

The application of science continually creates new ethical situations. It creates new duties, new conceptions of consequences of acts (Haldane). When it became known that leprosy was caused by bacteria which live in man's body, and not by devils or evil humors, the words "right" and "wrong" took on new meanings for every leper. When man becomes imbued with the idea that ethical codes may change as civilization changes, he may go further and conclude that various ethical codes or even various religions may all have some good and some bad in them and that they may be of approximately equal value. The theories of science change continually as the facts which furnish evidence change. New discoveries cause old beliefs to be discarded. Physics is not jealous of chemistry, but incorporates new discoveries and laws

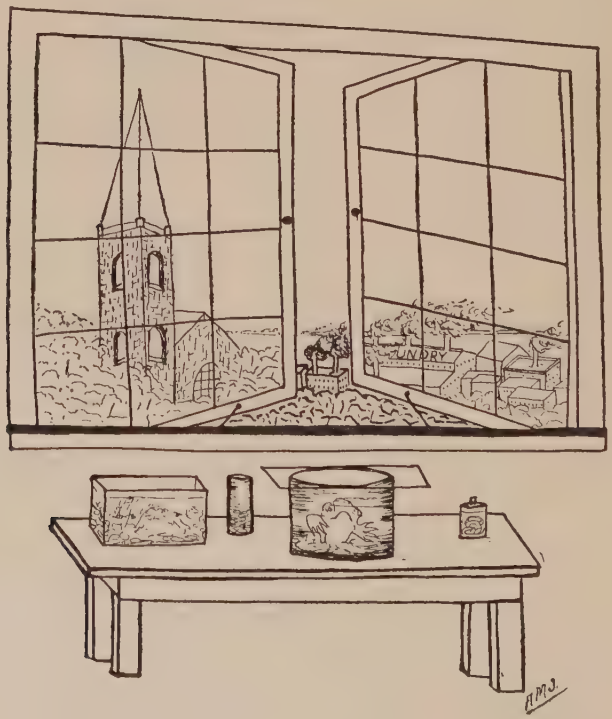
of its sister science into itself as soon as it can. Business is progressive and is continually throwing old marketing and manufacturing methods on civilization's scrap heap. Its slogan is "efficiency." Science and commerce, as well as religion, are making the world more brotherly and tolerant. Perhaps the religions of the future must be less self-sufficient and autocratic than those of the past. Their advocates must preach less about what God wills and more of "those who love their fellow men," for religion has its chief function in enabling man to live better with his fellows.

Science must help commerce with discoveries and inventions. Commerce must enable science to live while it discovers and invents, but it should not treat the recipient of its aid like a poor relative who receives a gratuity, nor should it make science a slave which does nothing but discover useful things. Religion must also depend on commerce for sustenance. It will doubtless in the future learn to obtain its incomes less as the tax collector of an autocratic ruler and more as a loving wife who has a joint checking account with her husband.

Civilization will continue to be upheld by her three supporters—Science, Commerce and Re-

ligion. Every private citizen should regret strife between her three sturdy upbearers. They must get along together. It is of no use for Science to say to Religion—"You are antiquated and unnecessary. Get out and let commerce and me carry the world!" People want religion and probably always will. When that arch-scientist, Huxley, was asked point-blank whether, if he were compelled to make a choice, he would choose materialism or idealism, he unhesitatingly said he would take idealism. Men live more for faith, hope, and charity than for their daily bread. It is of no use for Religion to say to Science, "Your discoveries are cataclysmic. They are destroying the society I have so carefully supported. Let me have back my old world!" Science must continue to weigh and measure. In the end truth will not hurt the world. It is of no use for Commerce to say to Science and Religion, "I am sensible. My feet are always on the ground. I am practical. You are both unnecessary. Let me carry the world alone." Commerce would be an incompetent fellow without the ethical standards and the sentimental loyalty to organization and duty which he gains through his association with Religion. His sinews would be soft and flabby without the continual support he receives from Science.

Every citizen should be proud of the great modern triumvirate. He may be more interested in one of them than in another, and hence feel more love and loyalty for his favorite, but all three should be given credit for their works. All three should get along together. The stability and success of our little world depends upon such amity.



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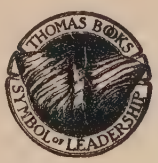
THIS BOOK

ENVIRONMENT AND LIFE

was set, printed and bound by The Collegiate Press of Menasha, Wisconsin. The Cover Design is by The Decorative Designers of Chatham, New Jersey. The type face is Caslon Old Style. The type is set 12 on 14 point (Monotype). The type page is 21 x 33 picas. The end sheets are 20 x 26—65 White Antique Tuftex. The jacket is 26 x 40—80 Gray Antique construction. The text paper is Warrens No. 66 Antique 32 x 44—120—(80 Pound). The binding is Holliston Extra Colors 297, Plain Pattern.



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